4. Carbon Sequestration

Background

Carbon sequestration plays an important role in the global carbon cycle. Green plants remove (sequester) carbon from the atmosphere through photosynthesis, extracting carbon dioxide from the air, separating the carbon atom from the oxygen atoms, returning oxygen to the atmosphere, and using the carbon to make biomass in the form of roots, stems, and foliage.

Every year in the United States and throughout the world a very large amount of carbon dioxide—on the order of 100 billion metric tons—is sequestered in biomass.[27] At the same time, carbon is released to the atmosphere from vegetative respiration, combustion of wood as fuel, degradation of manufactured wood products, consumption of biomass for food by animals, and the natural decay of expired vegetation. The net numerical difference, or flux, between carbon sequestration and release can be viewed as a measure of the relative contribution of biomass to the carbon cycle. World flux associated with Earth's living matter is difficult to measure, but biomass is thought to provide a net "sink" equivalent to about 5 billion metric tons carbon dioxide per year.[28]

Forests can play an important role in offsetting human-produced carbon emissions. On average, trees are approximately 25 percent carbon by weight (live trees are approximately 50 percent water by weight, and oven-dried wood is approximately 50 percent carbon by weight).[29] The amount of carbon a plant can sequester depends on a number of variables, including species and age, but can be quite large. For example, one large sugar maple tree is capable of removing more than 450 pounds of carbon dioxide from the atmosphere in a year. At that rate, preserving 29 trees per operating automobile in the United States would offset all U.S. automobile-related carbon dioxide emissions.[30]

Carbon sequestration on a national scale is substantial. The U.S. Environmental Protection Agency, relying heavily on the work of U.S. Forest Service Researchers Richard Birdsey and Linda Heath, estimates annual U.S. carbon sequestration (generally defined according to the guidelines of the Intergovernmental Panel on Climate Change) at 211 million metric tons carbon equivalent,[31] which offsets approximately 12 percent of annual U.S. anthropogenic emissions of greenhouse gases.[32]

Projects Reported

Seventy-one entities reported projects involving forestry or natural resources that sequestered carbon or reduced emissions in 1999 (Table 9). The reporters included 58 electric utilities, 3 operating subsidiaries of an independent power producer, 6 nonprofit organizations, a real estate company, a university, a fabricated metals product manufacturer, and a computer chip manufacturer. A total of 443 carbon sequestration projects were reported, an increase of 24 percent from the 1998 data year. Forestry projects were the second most commonly reported project type after electricity supply (453), accounting for 26 percent of all the projects reported for 1999 (see Table 2 in Chapter 1). The reported forestry projects were dispersed over a wide geographic area, including 45 States and 8 foreign countries. A total of 241 domestic and 61 international forestry projects were reported.

The total sequestration and reduction in emissions reported for 1999 declined by 22 percent from the previous year, to 9,698,053 metric tons carbon dioxide (Table 9). The decline resulted primarily from the completion of a World Parks Endowment preservation project and

[27]Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual*, IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 3 (Paris, France, 1995), p. 5.2, http://www.iea.org/ipcc.htm.

[28]Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996), p. 77.

[29]R.A. Birdsey, *Carbon Storage and Accumulation in United States Forest Ecosystems* (Washington, DC: USDA Forest Service, 1992), p. 12.

[30]Average mileage and fuel consumption for passenger cars from Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000), p. 53. Carbon dioxide emissions per mile driven and gallon of motor fuel from U.S. Department of Energy, *Sector-Specific Issues and Reporting Methodologies Supporting the General Guidelines for the Voluntary Reporting of Greenhouse Gases Under Section 1605(b) of the Energy Policy Act of 1992*, DOE/PO-0028 (Washington, DC, October 1994), Vol. 2, p. 4.19.

[31]U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998*, EPA-236-R-00-001 (Washington, DC, April 2000), p. 6-2, http://www.epa.gov/globalwarming/publications/emissions/us2000/index.html.

[32]U.S. athropogenic greenhouse gases emissions were 1,832.6 million metric tons carbon equivalent in 1999. Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1999*, DOE/EIA-0573(99) (Washington, DC, October 2000), p. vii.

Table 9. Number of Projects and Sequestration and Net Reductions Reported for Sequestration Projects, Data Years 1994-1999

Data Year	Number of Reporters	Number of Projects	Sequestration and Net Reductions (Metric Tons Carbon Dioxide)
1994	40	78	772,330
1995	62	199	1,247,430
1996	67	198	8,712,616(R)
1997	75(R)	309(R)	9,861,433(R)
1998	74	356	12,495,669
1999	71	443	9,698,053

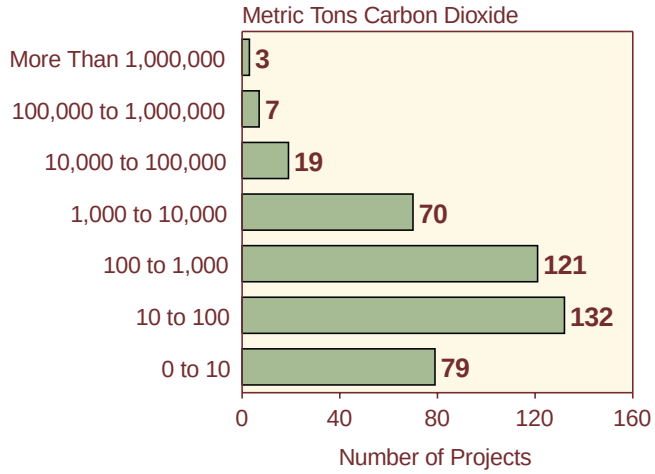
(R) = revised.
Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

from a downward adjustment of the sequestration estimate for the AES Thames CARE Agroforestry project.[33] Carbon sequestration projects typically are considerably smaller than projects that reduce emissions of carbon dioxide (such as electricity supply and energy end use). Of the forestry projects reported for 1999, 73 percent sequestered between 10 and 10,000 metric tons carbon dioxide equivalent (Figure 13), with a median reported reduction of about 110 metric tons.

A significant number (13 percent) of the reported projects were urban forestry projects, involving the planting of trees in urban and suburban areas.[34] Urban forestry projects are typically much smaller than forestry projects undertaken in rural or wilderness areas. The average carbon dioxide sequestration reported per urban forestry project for 1999 was just 158 metric tons. Projects in rural or wilderness areas are sometimes large: 10 such projects sequestered more than 10,000 metric tons carbon dioxide each in 1999. For the 431 projects for which data were reported, average sequestration for 1999 was 22,493 metric tons carbon dioxide equivalent per project.

Of the projects reported for 1999, most (352 or 79 percent) involved some kind of tree planting, which included afforestation, reforestation, urban forestry, and woody biomass production or agroforestry (Table 10).[35] These projects accounted for 11 percent of the sequestration (and related emission reductions) reported for 1999. Although only 39 forest preservation projects were reported, they accounted for 88 percent of the

Figure 13. Carbon Sequestration Projects by Amount of Carbon Sequestered, Data Year 1999



Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

sequestration reported for 1999. Ninety-two percent of the total sequestration for 1999 was reported on behalf of foreign projects, which include some very large forest preservation and agroforestry initiatives.

More than half (60 percent) of the reported forestry projects were undertaken in part to fulfill commitments made under the Climate Challenge program. In addition, 27 (6 percent) were undertaken as part of the U.S. Initiative on Joint Implementation (USIJI). Established under the Climate Change Action Plan (CCAP),[36] the

[33]World Parks Endowment estimated sequestration for the Bladen Sanctuary as the carbon (expressed as carbon dioxide) that would have been released had the forest been logged over a 6-year period from 1993 to 1998. World Parks Endowment estimated the avoided release for 1998 at 1.03 million metric tons carbon dioxide. No further sequestration was claimed for 1999. In its 1999 report, AES Thames revised sequestration estimates for all years for the CARE Agroforestry project. Reported sequestration for 1999 was 0.53 million metric tons carbon dioxide, as compared with 1.94 million metric tons reported for 1998, which was reduced to 0.59 million metric tons in this year's report.

[34]Urban forestry projects include projects reported as general tree planting projects on Form EIA-1605EZ.

[35]Afforestation is the planting trees in unforested areas. Reforestation is the planting of trees in forest areas that have recently been harvested. Urban forestry is the planting of trees individually or in small groups in urban or suburban settings. Agroforestry is the cultivation of trees in plantations for fuel or fiber.

[36]President William J. Clinton, *The Climate Change Action Plan* (Washington, DC, October 1993), Appendix II, http://www.gcrio.org/USCCAP/toc.html.

Table 10. Number of Sequestration Projects Reported by Project Type, Data Years 1994-1999

Data Year	1994	1995	1996	1997	1998	1999
Afforestation	26	38	38	91(R)	102	159
Reforestation	15	82	80	92	110	139
Urban Forestry	27	41(R)	42(R)	48(R)	57	58
Modified Forest Management	12	20	10	34(R)	42	43
Woody Biomass Production and Other Agroforestry	8	14	2	3	3	3
Forest Preservation	2	23(R)	30(R)	40(R)	47	39
Conservation Tillage	1	1	1	2	2	2
Other Projects	3	4	6	11	4	11

(R) = revised.

Notes: Urban forestry includes general tree planting projects reported on Form EIA-1605EZ. Some projects are counted in more than one category.

Source: Energy Information Administration, Forms EIA-1605 and EIA-1605EZ.

USIJI is a pilot program that seeks to encourage foreign-based emission reduction and carbon sequestration projects conducted by U.S. and non-U.S. partners. The following USIJI-approved forestry projects were reported to the Voluntary Reporting Program: the Rio Bravo Carbon Sequestration Pilot Project (Belize); Oregon State University's RUSAFOR-SAP project (Russia); PG&E's Reduced Impact Logging Project (Malaysia); the Noel Kempf Mercado Climate Change Action Project (Bolivia), and the Bilsa Biological Reserve (Ecuador).

Afforestation and Reforestation

Of the sequestration projects reported for 1999, 292 (66 percent) involved either afforestation or reforestation. The carbon sequestration and emission reductions reported for these projects totaled about 593,981 metric tons carbon dioxide, representing 9 percent of the total sequestration reported for 1999. All but one of the 292 afforestation and reforestation projects were domestic. The exception is Oregon State University's RUSAFOR-SAP project in Russia, which includes reforestation of two sites totaling 450 hectares, 50 hectares of which suffered a forest fire in 1992, and afforestation of another two sites totaling 450 hectares.

American Forests, a nonprofit conservation organization, and American Electric Power, Inc. (AEP), a large investor-owned utility, together accounted for over half (56 percent) of the 291 domestic afforestation and reforestation projects reported for 1999. American Forests reported a total of 131 projects under its Global ReLeaf Forests program, 28 of which were initiated in 1999. Global ReLeaf supports the restoration of U.S. forest ecosystems that have been damaged by natural events or human actions. American Forests plans to plant 20 million trees through Global ReLeaf by the year 2000. Through the end of 1999, 10.8 million trees had been planted, sequestering 73,873 metric tons carbon dioxide in 1999—enough to offset carbon dioxide emissions from about 11,000 automobiles.[37] All but 6 of the Global ReLeaf projects involved reforestation. AEP reported 19 afforestation projects on land owned by its operating companies, which sequestered a reported 81,697 metric tons carbon dioxide in 1999. Four of the projects were initiated in 1999.

A large part of the increase in the number of domestic afforestation and reforestation projects can be attributed to two domestic programs initiated in 1999 by the UtiliTree Carbon Company.[38] Shares in two new UtiliTree projects were reported by 26 of the participating utilities, resulting in reports of carbon dioxide sequestration for 52 additional projects in 1999.[39] The Upper Ouachita River Valley Bottomland Hardwood Restoration and the Overflow Bottomland Hardwood Restoration projects consist of 1,000 acres and 400 acres, respectively, of marginal agricultural farmland recently acquired by the U.S. Fish and Wildlife Service. UtiliTree has planted the sites with hardwood species such as green ash, bald cypress, sweet gum, willow oak, and nuttal oak, and they will be incorporated into existing National Wildlife Refuges. Two ongoing UtiliTree projects, Western Oregon Carbon Sequestration and Mississippi Valley Hardwood Restoration, were also reported by 28 participating utilities. Thus, UtiliTree accounted for 108 (68 percent) of the afforestation projects reported for 1999.

[37] Average mileage and fuel consumption for passenger cars from Energy Information Administration, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000), p. 53. Carbon dioxide emissions per mile driven and gallon of motor fuel from U.S. Department of Energy, *Sector-Specific Issues and Reporting Methodologies Supporting the General Guidelines for the Voluntary Reporting of Greenhouse Gases Under Section 1605(b) of the Energy Policy Act of 1992*, DOE/PO-0028 (Washington, DC, October 1994), Vol. 2, p. 4.19.

[38] The UtiliTree Carbon Company, managed by the Edison Electric Institute, is a partnership of 40 investor-owned electric utilities.

[39] One utility reported its share in only one of the two projects.

Urban Forestry

A total of 58 urban forestry projects were reported for 1999 by 37 reporters, all but two of which were electric utilities. For the 56 urban forestry projects for which estimates were developed, a total of 8,602 metric tons carbon dioxide was sequestered in 1999—an amount that would offset less than 0.1 percent of the emissions from a 1,000-megawatt coal-fired power plant.[40]

Urban forestry projects are unique, in that under some circumstances they can reduce energy consumption as well as sequester carbon. Shade trees planted near buildings reduce summer air conditioning requirements; in addition, trees can also act as windbreaks, reducing heating needs in the winter. Although the emission reductions associated with energy effects of urban forestry can be several times the sequestration benefits on a carbon dioxide equivalent basis, they are difficult to estimate. As a result, only four reporters submitted information on energy-related emission reductions for urban forestry projects (the reductions are included in the energy end use reduction totals in Chapter 3).

Forest Preservation

A total of 39 forest preservation projects were reported for 1999 by 34 reporters. All but four of the projects were foreign. The two largest forest preservation projects were reported by AES Hawaii and AES Shady Point, subsidiaries of the AES Corporation. Together, these two projects sequestered a reported 5.68 million metric tons carbon dioxide in 1999, representing 67 percent of the total sequestration reported for forest preservation projects.

Two utilities (AEP and PacifiCorp) reported on the Noel Kempf Mercado Climate Action Project in Bolivia, which was accepted by the USIJI in November 1996. The project, which involves the preservation of 634,286 hectares of land on the southern and western boundary of the Noel Kempf Mercado National Park by incorporating it into the park, includes the following components: (1) carbon dioxide emission reductions through the cessation of logging activities and the protection of forest land from conversion to agricultural use; (2) protection, regeneration, and preservation; and (3) leakage prevention.[41] The AEP and PacifiCorp shares of the project accounted for a reported increase in sequestration of 1.77 million metric tons carbon dioxide for 1999.

The World Parks Endowment reported three forest preservation projects located in Belize, Guatemala, and Ecuador that together have prevented emissions of an estimated 9.6 million metric tons carbon dioxide from 1991 through 1999. According to the World Parks Endowment, two of the preserved sites, the Bladen Sanctuary (Belize) and the Sierra de las Minas Reserve (Guatemala), would have been logged by 1998; therefore, no further increase in sequestration was reported for 1999. The third project reported was the Bilsa Biological Reserve (Ecuador), which, according to the World Parks Endowment, would have been logged from 1997 through 1999. Preserving the site avoided emissions of a reported 353,835 metric tons carbon dioxide annually over the 3-year period.

The Rio Bravo Carbon Sequestration Pilot Project, a forest preservation project in Belize, was included in the reports submitted by 28 utilities, each of which reported its prorated share of the total sequestration for the project. Begun in 1995, the project is being undertaken through a partnership between Cinergy Corporation, DTE/Detroit Edison, PacifiCorp, Wisconsin Electric Power Co., the UtiliTree Carbon Company, the Nature Conservancy, and a Belizean nongovernmental organization (Programme for Belize). The project includes the purchase of a 14,400-acre parcel of endangered forest threatened with conversion to agriculture. The entire project sequestered an estimated 807,317 metric tons carbon dioxide in 1999, of which 620,991 metric tons (77 percent) was reported to the Voluntary Reporting of Greenhouse Gases Program.[42]

Domestic forest preservation projects were reported by Alliant Energy, Tacoma Public Utilities, Wisconsin Public Service Corporation, and Whatcom Land Trust. Alliant Energy reported sequestering 1,597 metric tons carbon dioxide in 1999 by maintaining forested buffer lands around its power plants. Tacoma Public Utilities reported preserving nearly 11,000 acres of forest but did not estimate the sequestration achieved. Wisconsin Public Service Corporation reported forest preservation as a component of its afforestation and reforestation efforts, sequestering a reported 94,347 metric tons carbon dioxide in 1999. Whatcom Land Trust reported on its Canyon Lake Creek Community Forest Project, which permanently protects approximately 303 hectares of alpine forest containing one of the oldest forest stands in the Pacific Northwest. According to the Whatcom Land

[40] Assuming a power plant with a heat rate of 12,000 Btu per kilowatthour operating at 85 percent availability using subbituminous coal emitting 212.7 pounds of carbon dioxide per million Btu.

[41] Leakage refers to the migration of logging and land-clearing activities that would have occurred in the preserve to areas outside the preserve, which would offset the sequestration achievements of the project.

[42] Several UtiliTree participants and one of the utility partners did not submit reports to the Voluntary Reporting Program for data year 1999.

Trust, the planned clear-cut logging of this tract would have released an estimated 609,382 metric tons carbon dioxide in 1998. No additional sequestration was reported for 1999.

Modified Forest Management

Of the 43 modified forest management projects reported in 1999, 29 were associated with two related reduced-impact logging initiatives in Malaysia. The first initiative was a pilot project reported by PG&E Corporation for 1999.[43] Started in 1992, this project implemented new logging techniques with the goal of reducing logging damage by 50 percent. The new techniques include pre-cutting of vines, directional felling, and planned extraction of timber on impact-reducing skid trails. Twenty-eight utilities reported their shares in the second initiative—a full-scale project sponsored by the UtiliTree Carbon Company that introduced reduced-impact logging practices to 2,422 acres of forest beginning in 1997. Together, the two initiatives increased sequestration by a reported 42,377 metric tons carbon dioxide equivalent in 1999.

Between 1991 and 1999, AEP selectively harvested more than 4,300 acres of upland central hardwood and bottomland hardwood stands to improve growing space relationships and maximize growth rates. The efforts increased sequestration on the affected tracts by a reported 5,804 metric tons carbon dioxide in 1999. DTE Energy / Detroit Edison conducted similar thinning operations in previously unmanaged wood lots and reported increasing sequestration by about 1,400 metric tons in 1999. The Pacific Forest Trust, a California-based nonprofit organization, reported implementing unspecified forest management improvements on a 351-acre forest that increased sequestration in 1999 by a reported 68,194 metric tons carbon dioxide. Enhanced forest management activities were also reported by Alliant Energy and Wisconsin Public Service Corporation as components of their afforestation or reforestation activities.

Forest Plantations

Forest plantations include woody biomass production and agroforestry. Woody biomass production is the cultivation of trees in intensively managed plantations for the purpose of producing fuel or fiber. Agroforestry involves mixing trees with annual crops to provide wind shelter, stabilize soil, and produce fuel wood and fruit crops.

Woody biomass production projects were reported by Minnesota Power and J.M. Gilmer and Company. Minnesota Power has negotiated contracts with land owners for the planting of hybrid poplars, which was conducted on 2,672 acres of cleared land between 1995 and 1997. The trees, which reportedly sequestered more than 22,000 metric tons carbon dioxide in 1999, will be harvested after 12 years for use by the forest products industry or as biomass for energy production. J.M. Gilmer and Company established a short-rotation cottonwood plantation on a river bottom site in Alabama. The cottonwoods will also be harvested on a 12-year rotation and used as biofuel (displacing fossil fuel) or for pulpwood.

AES Thames reported an agroforestry project in Guatemala that involves establishing a plantation of fruit, pulp, and fuel wood trees. Using a revised estimation method, AES Thames reported that its project sequestered 480,808 metric tons carbon dioxide in 1999.

Conservation Tillage and Other Sequestration Projects

Not all the carbon sequestration projects reported for 1999 involved conventional forestry. Other projects reported involved conservation tillage, reuse of utility poles, and restoration of terrestrial, wetland, and marine habitats. New projects reported for 1999 included a wetland reclamation project reported by Atlantic Energy, Inc. and seagrass and marsh grass plantings conducted by the Greater Caribbean Energy & Environment Foundation. Atlantic Energy planted native wetland tree species to reclaim 6 acres of a wetland that had been filled with dredge spoils. Greater Caribbean Energy & Environment Foundation planted seagrass at five marine sites in Florida and Texas that had been disturbed effluents from power plant cooling towers or by other sources of pollution. Greater Caribbean also conducted plantings at a sixth site to restore marshland habitat.

Other previously reported carbon sequestration projects include the following: conservation tillage projects reported by PP&L Resources, Inc. and Alliant Energy; UNICOM's planting of Illinois prairie grasses on company properties and the reuse of utility poles; Entergy's restoration of two wetland sites totaling 5,500 acres by planting grasses and making hydrological modifications; and Alliant's restoration of 700 acres of abandoned old field to prairie / savanna habitat. These projects were reported to have sequestered a total of 67,615 metric tons carbon dioxide in 1999.

[43]This project was originally sponsored by New England Power Company and reported by its parent company, New England Electric System (NEES) Company. In August 1998, USGen New England, Inc. (USGenNE) completed the acquisition of New England Electric System (NEES) Company's hydroelectric and fossil power generation business previously operated by New England Power. As part of the acquisition, the rights to the emission reductions and carbon sequestration achieved by this and other projects were transferred to USGenNE. For 1999, the activities previously reported by USGenNE were incorporated into the report submitted by its parent, PG&E Corporation.